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⑤④ Novel expression plasmids and their use in the method for expressing prochymosin coding gene in E. coli.

⑤⑦ Improved methods are provided for replication and expression of prochymosin coding gene in E. coli. Novel expression plasmids having prochymosin coding gene operatively attached to the E. coli trp operon have been developed. These plasmids have been inserted into E. coli host cells by transformation; providing new strains to E. coli with high expression capability. The techniques for preparing such expression plasmids and E. coli strains derived therefrom are described. The modified cells, under appropriate cultivation conditions, produces a substantial amount of prochymosin which on activation (viz., in the form of chymosin) displays milk-clotting activity. The genetically engineered new strains of E. coli have been deposited with the Fermentation Research Institute, Ibaragi, Japan under the Budapest Treaty. The methods are thus useful in the massive production of prochymosin by fermentation, and are superior to the known art in the field.

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NOVEL EXPRESSION PLASMIDS AND THEIR USE IN THE METHOD FOR
EXPRESSING PROCHYMOSIN CODING GENE IN E. coli

1 BACKGROUND OF THE INVENTION

This invention relates in general to Genetic Engineering, and more specifically to the production of recombinant DNA containing prochymosin coding gene, and
5 to the utilization of the same to produce microorganisms for the volume production of prochymosin.

The term, "Genetic Engineering" refers to the in vitro technique of forming recombinant DNA containing exogenous genes and a suitable vector, selecting a DNA
10 on the basis of the desired genetic information, and introducing the selected DNA into a suitable host microorganism, whereby the foreign genetic information becomes part of the genetic complement of the host. The genetically engineered microorganism prepared by this
15 technique is capable of expressing the foreign gene in its cells under appropriate conditions of cultivation, and producing a substance (e.g. enzymes, proteins, hormones or the like) for which the gene will code.

The enzymatic protein chymosin is also known
20 as rennin. It is the major proteolytic protein found in the stomach of the pre-ruminant calf, and is responsible for clotting milk. Chymosin has therefore long been used for coagulating milk casein in cheese making. It has 323 amino acids and a molecular weight of 35,652.

1 It is recognized that two forms of chymosin (A and B)
are possible. These two forms differ at amino acid
codon 286 (nucleotide 857). The codon GAT in chymosin A
would be codon GTT in chymosin B.

5 Prochymosin (prorennin) is a precursor of chymosin having 42 additional amino acids at the amino terminus of the chymosin molecule, and it is converted to chymosin under acidic conditions by losing the additional amino acids. Prochymosin has 365 amino acids and
10 a molecular weight of 40,777. The complete amino acid sequence of prorennin has been described in B. Foltmann et al, Proc. Natl. Acad. Sci. USA, 74,231 (1977). The published sequence later proved to be incorrect at a number of amino acid sites. The revised sequence is
15 therefore given in FIG. 1.

Since chymosin is secreted by the mucous membrane of the abomasum of a newly born calf, it is obtained from the stomachs of calves in commercial production. There are several serious problems associated
20 with the obtaining of chymosin from calves: this process involves a number of complicated procedures which present many difficulties when attempting to secure large amounts. It is also costly, and has not been able to meet commercial demands in recent years. For these
25 reasons, some substitutes for chymosin have become acceptable in cheese making. One such substitute is a microbial rennet which is produced by Mucor pusillus,

1 Mucor miehei or Endothia parasitica. However, this
microbial rennet has moderately strong proteolytic acti-
vity and is not as suitable in cheese ripening as chymo-
sin itself which has a specific yet weak proteolytic
5 activity.

Accordingly, there is still great significance
in the supply of a large amount of chymosin from a com-
mercial point of view.

10 SUMMARY OF THE INVENTION

The process of this invention employs novel
expression plasmids which are formed by isolating DNA
inserts having prochymosin coding genes from previously
constructed recombinant plasmids, and inserting said DNA
15 into suitable vectors. The expression plasmids are then
used to transform susceptible microorganisms under con-
ditions where transformation can occur. The microorga-
nism is grown under conditions which will favor the har-
vesting of transformants which contain the recombinant
20 expression plasmid. Once a host microorganism has been
properly transformed, microbial cells can be repeatedly
multiplied by culturing the microorganism in an
appropriate growth medium, which will express the
prochymosin coding gene to produce prochymosin in their
25 cells. Thus, the volume production of prochymosin by
microorganisms in fermentation culture will become
feasible and provide calf chymosin at reasonable cost.

1 References relating to this invention are U.S.
Pat. No. 4,237,224 (Cohen and Boyer), Japanese Patent
Application Sho 56-131,631 to T. Beppu, K. Nishimori, et
al, Gene, 19,337 (1982), European Patent Application Publication No.
5 68691 to Celltech Ltd. and European Patent Application Publication
No. 57350 to Collaborative Research Inc. Particularly,
in the copending application Japanese Patent Application
Sho 56-131,631 corresponding to Japanese Patent
Application Kokai No. 32896/83, filed August 24, 1981
10 and assigned to the same assignee, an expression plasmid
containing the lac UV promoter and almost entire
sequence of prochymosin cDNA fused to the N-terminal
amino acids of E. coli beta-galactosidase is disclosed.

One of the objects of this invention is to
15 provide specific prochymosin genes for use in the
construction of novel expression plasmids.

Another object of this invention is to provide
such novel expression plasmids and utilize them to
obtain a high expression of prochymosin in microbial
20 host cells.

Another object of this invention is to provide
methods for producing novel expression plasmids.

Another object of this invention is to employ
the E. coli tryptophan operon promoter in place of the
25 E. coli lac operon promoter.

Still another object of this invention is to
obtain genetically engineered microorganisms which will

- 1 be capable of producing substantially greater amounts of
prochymosin than could be produced by the hitherto known
microorganisms.

- A still further object of this invention is to
5 provide a method for producing prochymosin using geneti-
cally engineered microorganisms.

One more object of this invention is to pro-
vide prochymosin itself produced according to the
above-mentioned methods.

- 10 Throughout the Specification, "prochymosin
gene" is defined as any sequence of nucleotides which
will encode the prochymosin molecule. Any portion of
the nucleotide sequence as described in FIG. 1 can be
used.

- 15 In accordance with a method of this invention,
the expression of prochymosin in host cells and their
production can be accomplished in terms of the following
steps:

1. Specific prochymosin genes are isolated from
20 known recombinant plasmids as described pre-
viously by digestion with appropriate restric-
tion enzymes.
2. The prochymosin genes are ligated together
with a vector and a translational initiation
25 codon to form an expression plasmid. If the
ligated prochymosin genes do not cover the
entire coding sequence for prochymosin, an

1 additional synthetic oligonucleotide carrying
a missing portion of the coding sequence can
be fused to the ligated genes. The synthetic
DNA piece may also carry a translational codon
5 preferably preceeding the tip of the prochymo-
sin gene portion.

3. Suitable host cells are transformed with the
expression plasmid by calcium chloride treat-
ment.

10 4. Ampicillin-resistant transformed cells are
selected.

5. The transformed cells are grown by standard
culturing techniques.

6. Crude extracts of the cells are tested for the
15 presence of prochymosin by the
radio-immunoassay or protein blotting method.

One recombinant plasmid of particular interest
is referred to as pCR301, and is described in Nishimori
et al., Gene, 19, 337 (1982). Descriptions of methods
20 for constructing other plasmids carrying prochymosin
cDNA may be found in Nishimori et al., J. Biochem., 90,
901 (1981) and other references previously referred to.
These plasmids are useful as a source of the prochymosin
genes and normally are constructed in the manner
25 described below;

1. Messenger RNA(mRNA) of the prochymosin gene is
isolated from the fourth calf stomach.

- 1 2. The mRNA is converted to double-stranded DNA
 by conventional means.
3. Synthetic linkers are attached to both ends of
 the double-stranded cDNA.
- 5 4. The cDNA molecule is integrated into a
 suitable vector plasmid (e.g. pBR 322).
5. The recombinant plasmid is then introduced
 into host cells by transformation.
6. Recognition of correct clones is accomplished
10 by the method of colony hybridization and
 hybrid-arrested translation.
7. DNA inserts in the clones are sequenced by the
 method of Maxam and Gilbert.

Protein resulting from a prochymosin coding
15 gene devoid of some tip portion of the coding sequence
may be called "prochymosin like protein." Prochymosin
having methionine attached to its N-terminus may be
called N-terminal methionyl prochymosin. Throughout the
Specification, both may be referred to as prochymosin.

20 As will be later described in detail, by
reerring to preferred embodiments, it should be
understood that this invention provides:

1. A method for expressing a prochymosin coding
 gene in E. coli host cells, wherein said gene
25 is derived from transformants containing
 cloned prochymosin cDNA, said method
 comprising:

1 isolating said gene from the transformants;
attaching by ligation a transcriptional pro-
moter and a translational initiation codon
thereto to form an expression plasmid; and
5 selecting transformed cells that have high
levels of expression of prochymosin, N-
terminal methionyl prochymosin or prochymosin
like protein, said gene having at least from
the fifth coding codon to the end of the
10 coding sequence for prochymosin in addition to
being fused to the N-terminal portion of the
trp L or trp E gene.

2. A method for expressing a prochymosin coding
gene in E. coli host cells, wherein said gene
15 is derived from transformants containing
cloned prochymosin cDNA, said method
comprising:
isolating said gene from transformants;
ligating onto said gene a synthetic oligo-
20 nucleotide carrying a complementary portion of
the prochymosin coding sequence which has been
deleted from said gene; attaching thereto by
ligation a transcriptional promoter and a
translatinal initiation codon when not present
25 in said synthetic oligonucleotide to form an
expression plasmid; transforming host cells
with the expression plasmid; and selecting

1 transformed cells that have high levels of ex-
pression of prochymosin or N-terminal
methionyl prochymosin, said synthetic oligo-
nucleotide optionally carrying a translational
5 initiation codon.

3. A method for producing prochymosin by means of
expression of a prochymosin coding gene in E.
coli host cells, wherein said gene is derived
from transformants containing cloned prochymo-
10 sin cDNA, said method comprising;
isolating said gene from the transformants;
attaching by ligation a transcriptional pro-
moter and a translational initiation codon
thereto to form an expression plasmid; trans-
15 forming host cells with the expression
plasmid; selecting transformed cells that have
high levels of expression of prochymosin, and
cultivating the transformed cells in an appro-
priate nutrient medium.

20 4. An expression plasmid comprising a prochymosin
coding gene and a vector operatively attached
thereto, said vector being derived from pBR32
plasmid and containing a transcriptional pro-
moter and a translational initiation codon.

25 It is also to be understood that this inven-
tion encompasses specific prorennin coding gene, coding
sequences containing them, methods for constructing

1 novel expression plasmids; transformed microorganisms;
and prochymosin produced therefrom.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 shows the complete nucleotide sequence
5 for prochymosin coding gene.

FIG. 2 shows restriction enzyme maps for vector plasmids used in this invention.

FIG. 3 shows restriction enzyme maps for expression plasmids used in this invention.

10 FIG. 4 shows the DNA sequence in the vicinity of the trp promoter in pOCT2 plasmid.

FIG. 5 is a schematic diagram for the construction of pTRE1 from pOCT3 by way of pOCT2.

FIG. 6 is a schematic diagram for the
15 construction of pTRL1 from pOCT2 and pBR322.

FIG. 7 is a schematic diagram for the construction of pTRP1 from pTRE1.

FIG. 8 is a schematic diagram for the construction of pCR501 from pCR301 and pTRE1.

20 FIG. 9 is a schematic diagram for the construction of pCR601 from pCR301, pTRE1 and pTRL1.

FIG. 10 is a schematic diagram for the construction of pCR701 from pCR501 and pTRP1.

25 DESCRIPTION OF THE PREFERRED EMBODIMENT

Host Microorganism

Any microorganism capable of accepting and

1 replicating the desired vector plasmids can be used but,
for practical reasons, derivatives of E. coli c 600 are
used in this invention. Particularly preferred strain
is E. coli c600 $r_k^- m_k^-$ Cells are grown under conven-
5 tional culturing conditions. For example, culture media
for the E. coli strain can be:

	L Broth	<u>per liter</u>
	Bacto Tryptone	10g
	(Difco Lab., Detroit)	
10	Bacto Yeast Extracts	5g
	(Difco Lab., Detroit)	
	NaCl	10g
	Glucose	2g
15	M9 Broth	<u>per liter</u>
	Na_2HPO_4	6g
	KH_2PO_4	3g
	NaCl	5g
	NH_4Cl	1g
20	$CaCl_2$	15mg
	$MgSO_4 \cdot 7H_2O$	0.1g
	B1 (thiamine HCl)	5mg if required
	Casamino acid	2.5g
	Glucose	5g
25	Ampicillin	50mg
	3-beta-Indolylacrylic acid	15mg
	Conventionally, transformation experiments are	

1 conducted in LB medium containing 50 ug/ml of ampicillin
according to the method of Norgard (Gene, 3, 279 (1978).
In standard techniques, E. coli cells are grown to a
density of from 10 to 30×10^{12} cells per liter at a tem-
5 perature of from 30°C to 40°C.

Promoter

In order to have cloned genes expressed in
host cells, it is necessary to equip vector plasmids
with a suitable promoter; several promoters can be used
10 to obtain expression as long as they are compatible with
the host cells. Desirably, the E. coli tryptophan
operon promoter is used in this invention.

Recombinant Plasmids

pCR301

15 In accordance with this invention, genes are
conveniently available from the primary recombinant
plasmids as described previously. These plasmids con-
tain a prorennin coding gene with variable sizes and
some of them have been mapped precisely by restriction
20 enzyme digestion. Therefore, by cutting with
appropriate restriction enzymes, useful portions of the
prorennin coding genes can be separated, and used as a
source of DNA for a second cloning into a vector
plasmid. A representative of such plasmids is pCR301.
25 Plasmid pCR301 contains the lactose operon promoter and
almost entire prochymosin gene sequence (from nucleotide
#13 to #1095) only devoid of the first four codons.

1 This plasmid is derived from pBR322 plasmid (F. Bolvar
et al., Gene, 2, 95 (1977)). The nucleotide sequence
between the initiation codon ATG and the beginning of
the cloned procymosin gene is illustrated below (this
5 sequence corresponds to the nucleotide coding for the ten
N-terminal amino acids of beta-galactosidase):

5' - ATG GCC ATG TTA ACG GAT TCA CTG
Met

beta-galactosidase

GAA TTC CGG - 3'
Arg

10

prochymosin

A restriction enzyme map for pCR301 is shown
in FIG. 3.

pOCT2

15 Plasmid pOCT3, the precursor of pOCT2, is a
pBR322 plasmid into which a DNA fragment having the trp
promoter-operator, trp L and trp E' has been integrated
at its EcoRI site. Said trp promoter-operator portion
(- 0.5 Kb) is originally extracted from plasmid p trp
20 ED5-1 (R.A. Hallewell and S. Emtage, Gene, 9, 27
(1980)). This DNA is filled in by means of T₄ D poly-
merase, to which a EcoRI linker is annexed. The
resulting DNA fragment is inserted into the EcoRI site
of pBR 322. Plasmid pOCT3 was kindly provided by
25 Professor K. Matsubara at Osaka University, School of
Medicine. The trp operon DNA is cut out from pOCT3 by
digestion with EcoRI and, once isolated, it is then put

1 back to the EcoRI site of pOCT3 in such a manner that
the cut ends become switched around, leading to pOCT2.
Thus the transcriptional direction of pOCT3 is opposite
to that of pOCT2; it is clockwise in pOCT2 (5' to 3')
5 whereas counterclockwise in pOCT3. Fig. 4 shows the
DNA sequence (about 300 bases) in the vicinity of the
trp promoter in pOCT2 plasmid.

Fig. 5 is a schematic diagram for the
construction of pOCT3 from pOCT2. A restriction enzyme
10 map for pOCT2 is shown in FIG. 2.

pTRE1

Plasmid pTRE1 is derived from pOCT2 and has a
single EcoRI site since the other EcoRI site near the
ampicillin resistant region has been removed from pOCT2.
15 This plasmid contains the intact trp operon part of
pOCT2 as shown in FIG. 2. The construction of pTRE1 is
accomplished in the following manner.

Plasmid pOCT2 is partially digested with
EcoRI, resulting in the cleavage of the EcoRI site near
20 the ampicillin resistant region. The single stranded-
portions are then repaired by means of DNA polymerase
and the repaired ends are joined using T₄ DNA ligase to
produce pTRE1.

A restriction enzyme map for pTRE1 is shown in
25 FIG. 2. Fig. 5 shows a schematic diagram for the
construction of pTRE1 from pOCT2.

1 pTRL1

Plasmid pTRL1 has a DNA portion from pOCT2 bounded by EcoRI and RSaI sites. This portion comprises 360 base pairs (from an unidentified EcoR site to RSaI site in the trp L region), some of which are sequenced as shown in FIG. 4. The construction of pTRL1 is accomplished in the following manner.

Plasmid pOCT2 is cleaved with EcoRI and then partially digested with RSaI to yield a 360 base pair fragment containing the trp promoter region (trp L). This fragment is ligated with the EcoRI linker at the cut RSaI site. Digestion with EcoRI produces a fragment with cohesive ends. This fragment is then inserted into the EcoRI site of pBR322 to afford two kinds of recombinant plasmids. Plasmid pTRL1 is the one wherein the transcriptional direction from the trp promoter is counter-clockwise.

A restriction enzyme map for pTRL1 is shown in FIG. 2. FIG. 6 is a schematic diagram for the construction of pTRL1 from pOCT2.

pTRP1

Plasmid pTRP1 has a DNA portion from pTRE1 bounded by HpaI and ClaI sites. This portion comprises about 4640 base pairs originally derived from pBR322. The plasmid has also another DNA portion from pTRE1 bounded by HpaI and TaqI sites. This portion comprises 32 base pairs corresponding to the trp L promoter. The

1 construction of pTRP1 is accomplished in the following manner.

Plasmid pTRE1 is cleaved with HpaI and ClaI to yield an about 4640 bp linear DNA fragment. Both
5 fragments are joined together by ligation to produce pTRP1. A restriction enzyme map for pTRP1 is shown in FIG. 2. FIG. 7 is a schematic diagram for the construction of pTRP1 from pTRE1.

Expression Plasmids

10 Again using standard techniques as outlined previously, a desired DNA fragment containing the cloned prochymosin gene is extracted from a transformant, and cleaved with restriction enzymes; the vector plasmid is similarly cleaved; and the fragments are mixed and
15 ligated. These steps have led to the construction of expression plasmids, pCR501, pCR601, and pCR701 which are designed to facilitate to obtain expression of prochymosin in E. coli.

pCR501

20 Plasmid pCR501 contains a DNA portion of pTRE1 fused to about 1,000 nucleotides from pCR301, which code for the procymosin molecule. The construction of pCR501 is accomplished in the following manner.

Plasmid pTRE1 is cut with EcoRI and single-
25 stranded portions are removed by means of S1 nuclease. The EcoRI linker (GGATTTC/CCTTAAGG) is linked to the blunt end using T₄ DNA ligase. This DNA is next

1 digested with EcoRI and SalI to produce linear DNA
segment (a) (ca. 4210bp). Plasmid pCR301 is cut with
EcoRI and KpnI to obtain DNA segment (b). This DNA
segment is a 246 bp sequence containing the prochymosin
5 gene fused to the residual beta-glactosidase coding
gene. Similarly, pCR301 is cut with KpnI and SalI to
obtain DNA segment (c). This DNA is a 1025 bp sequence
of the prochymosin gene including its C-terminus. Each
DNA segment is ligated together by means of T₄ DNA
10 ligase. E. coli strain C600 is transformed with the
ligated DNA, and ampicillin resistant colonies (pCR501)
are selected.

As shown in FIG. 3, analysis of pCR501 by
restriction enzyme cleavage has revealed that pCR501 con-
15 tains the trp operon promoter and about 1,000 nucleoti-
des coding for prochymosin (nucleotide #13 to the end of
the gene, viz. 5th codon to 365th). FIG. 8 shows a
schematic diagram for the construction of pCR501 from
pCR301 and pTRE1.

20 Following the method of Maxam-Gilbert, the
nucleotide sequence between the initiation ATG codon and
the beginning of prochymosin gene (5th codon) has been
analyzed to be:

25 5' - ATG CAA ACA CAA AAA CCG ACT GGG GAA TTC CGG - 3'
Met Arg
trp E region prochymosin

1 Transformed cells carrying the plasmid will
express the cloned gene and produce prochymosin under
the control of the trp E promoter.

The prochymosin produced in this manner lacks
5 an amino acid sequence of the genuine prochymosin which
corresponds to that from the 1st to the 4th amino acid
at the N terminus, but contains, in its place, eight
amino acids (methionine and others) resulting from the
above-stated trp E promoter coding sequence as well as
10 two amino acid residues resulting from beta-
galactosidase. This prochymosin is therefore called
prochymosin like protein.

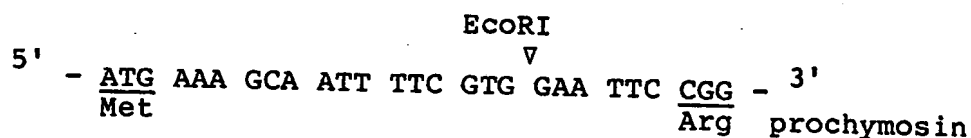
pCR601

Plasmid pCR601 contains a DNA portion of pTRE1
15 and a 56 bp fragment from pTRL1 fused to the same coding
sequence for prochymosin present in pCR501. The
construction of pCR601 is accomplished in the following
manner.

Plasmid pTRE1 is cut with HpaI and SalI to
20 produce a linear 4010 bp segment (DNA (d)). Next,
plasmid pTRL1 is cut with HpaI and EcoRI to produce a 56
bp segment (DNA (e)) containing the trp L promoter.
both segments are mixed and ligated together with DNA
(b) and (c) (both obtained previously from pCR301), by
25 means of T₄ DNA ligase. E. coli strain c 600 is trans-
formed with the resulting ligated DNA and ampicillin
resistant colonies (pCR 601) are selected.

1 As shown in FIG. 3, analysis of pCR601 by
restriction enzyme cleavage has revealed that pCR601
contains the trp L promoter and about 1,000 nucleotides
coding for prochymosin (nucleotide #13 to the end of the
5 gene, viz, 5th codon to 365th). FIG. 9 shows a schema-
tic diagram for the construction of pCR601 from pCR301,
pTRE1 and pTRL1.

Following the method of Maxam-Gilbert, the
nucleotide sequence between the initiation ATG codon and
10 the beginning of prochymosin gene (5th codon) has been
analyzed to be:



trp L region

15

Transformed cells carrying the plasmid will
express the cloned prochymosin gene and produce prochy-
mosin under the control of trp L promoter.

The prochymosin produced in this manner lacks
20 an amino acid sequence of the genuine prochymosin which
corresponds to that from the 1st to the 4th amino acid
at the N terminus, but contains, in its place, six amino
acids (methionine and others) resulting from the above-
stated trp L promoter coding sequence as well as two
25 amino acid residues resulting from beta-galactosidase.
This prochymosin is therefore called prochymosin like
protein.

1 pCR701

Plasmid pCR701 contains a DNA portion of pTRP1 and a synthetic nucleotide piece fused to a prochymosin coding sequence from pCR501. The construction of pCR701 is accomplished in the following manner.

Plasmid pTRP1 is cut with Hind III and Sal I to obtain liner DNA segment (f) (about 4050 bp). Plasmid pCR501 is cut with BamHI and SalI to obtain liner DNA segment (g) (1264 bp). A synthetic oligo-nucleotide having a 22bp is synthesized, which is the sequence of:

5' AGCTTATGGCTGAGATCACCAG 3'

3' ATACCGACTCTAGTGGTCCTAG 5'

This DNA segment (f) makes up for the nucleotide sequence that has been removed by digestion with Bam HI which cuts the 14th nucleotide of prochymosin gene. The three segments (f), (g) and (h) are ligated together by means of T₄ DNA ligase. E. coli c600 is transformed with the ligated DNA and ampicillin resistant colonies (pCR701) are selected.

As shown in FIG. 3, analysis of pCR701 by restriction enzyme cleavage has revealed that pCR701 contains the trp L promoter and the entire prochymosin coding sequence (i.e. nucleotide #1 to the end of the gene, vl2, 1st codon to 365th). FIG. 10 shows a schematic diagram for the construction of pCR701 from pTRP1 and pCR501.

1 As determined by the method of maxam-Gilbert,
the SD (Shinon and Delgarno) region is located 13
nucleotides away from the ATG initiation codon pre-
ceeding the 1st codon of the prochymosin gene (see
5 below).

TaqI HindIII

5' - AAGG GTA TCGATAAGCTT ATG GCT - 3'
SD Met Ala
ClaI

Transformed cells carrying the plasmid will
10 express the prochymosin gene and produce prochymosin
under the control of the trp L promoter.

The prochymosin produced in this manner is N-
terminal methionylprochymosin in which methionine
arising from the initiation codon ATG is fused to the N ter-
15 minus of the genuine prochymosin.

Expression of prochymosin in E. coli

A portion of the full-growth culture (in LB
medium) of E. coli cells transformed with the expression
plasmids is grown in M9 broth containing
20 3-beta-indolylacrylic acid (15 µg/ml) and ampicillin (50
µg/ml). Cells are harvested when propagation reaches
maximum. The cells are then destroyed by sonication
treatment and a cell-free extract is obtained. This
extract is subjected to electrophoresis in a polyacryla-
25 mide gel containing SDS. The product protein is
detected by the protein blotting method. Following the
above procedures or radioimmunoassay, each transformant

1 strain containing pCR501, pCR601 or pCR701 has been
tested for its ability to produce prochymosin. Analysis
by autoradiography (Nishimori, Gene, 19, 337 (1982) has
revealed that every strain gives a protein band the size
5 of which is equal to that of the authentic prochymosin.
In addition, the level of production of prochymosin has
been estimated to be more than 300,000 molecules per
cell. Similar results have been obtained by an analysis
using radioimmunoassay.

10 These results have shown that prochymosin is
produced in E. coli cells carrying plasmid pCR501,
pCR601 or pCR701 under the transcriptional control of
the E. coli trp operon promoter and that the levels of
production are substantially greater than those pre-
15 viously reported under the control of the E. coli lac
operon. Even higher levels of production will be
possible by using the same scheme in accordance with
this invention and by obtaining fusions of the trp pro-
moter closer to the initiation codon of prochymosin
20 which preferably proceeds the tip of the prochymosin
gene.

E. coli strains prepared by processes
according to this invention are exemplified by cultures
deposited with the Fermentation Research Institute,
25 Ibaraki, Japan under the Budapest Treaty, and are iden-
tified by the Accession number designated to each
strain.

1 This invention will be described in some
detail by way of illustration and example; nevertheless,
it should be understood that certain changes and modifi-
cations be practiced within the scope of the invention.

5 EXAMPLE

Throughout the following examples, TEN buffer
solution is meant to be a solution containing
Tris-HCl(20mM), NaCl(50mM) and EDTA(1mM) with a pH of
about 7.5.

10 Example 1.

Preparation of pTRE1 Plasmid

Plasmid pOCT2 was partially digested with
EcoRI by incubation at 20°C for 7.5 min in a 30 μ l solu-
tion containing Plasmid (1.5 μ g in 15 μ l TEN), EcoRI
15 (2.5 U, 0.5 μ l TEN), EcoRI buffer (3 μ l), and H₂O (11.5
 μ l). After agarose gel electrophoresis, the desired
DNA was isolated (in 40 μ l TEN) and this was heated at
60°C for 5 min. To this DNA solution (40 μ l) was added
DNA polymerase I (4 U, 4 μ l TEN), 16 mM ATP (4 μ l),
20 polymerase buffer solution (6 μ l), and H₂O (2 μ l). The
resulting mixture (a total volume of 60 μ l) was incu-
bated at 25°C for 30 min. After addition of 0.25 M EDTA
solution (4 μ l) followed by phenol and ether treatment,
DNA was precipitated with ethanol. The precipitate was
25 dissolved in a solution (10 μ l) containing T₄ DNA ligase
(1 U, 1 μ l), 3 mM ATP (2 μ l), ligase buffer solution (2
 μ l) and H₂O (5 μ l), and this was incubated at 22°C for 2

- 1 h. After incubation, the DNA was precipitated with
ethanol and dissolved in TEN solution. This solution
was used to transform the calcium-treated E. coli C 600
strain. One of twelve colonies, there was obtained two
5 transformants containing pTRE1.

Example 2

Preparation of pTRL1 Plasmid

i) Preparation of DNA Segment (1)

- Plasmid pOCT2 was cut with EcoRI at 37° C for
10 2 h in a 120 µl solution containing Plasmid (10.6 µg in
100 µl of TEN), EcoRI buffer (12 µl), and EcoRI (40 U, 8
µl of TEN). After incubation, the DNA was precipitated
with ethanol and the precipitate was dissolved in 50 µl
of TEN. The cut DNA was partially digested with RsaI by
15 incubation at 20°C for 10 min in a 60 µl solution con-
taining DNA (49 µl of TEN), BamHI buffer (6 µl), H₂O
(3 µl), and RsaI (20 U, 2 µl of TEN). The doubly cut
DNA was precipitated with ethanol and the precipitate
was dissolved in 20 µl of TEN. The dissolved solution
20 was then applied to polyacrylamide gel electrophoresis.
After electrophoresis, a 364 bp linear DNA (0.16 µg in
40 µl of TEN) was isolated. Meanwhile, EcoRI linker was
kinased with T₄ polynucleotide kinase at 37°C for 1 h in
a 20 µl reaction mixture containing the linker (5 µg, 5
25 µl TEN), ATP (3mM, 2 µl), kination buffer (2 µl), H₂O (9
µl), and the kinase (22U in 2 µl TEN). The kination
mixture (20 µl) was added to the above DNA solution (35

1 μ l), followed by addition of T_4 DNA ligase (5U, 5 μ l
TEN), ligase buffer (4 μ l), and ATP (6mM, 7 μ l). The
total mixture (71 μ l) was ligated together by incubation
at 22°C for 2 h. The ligated DNA was precipitated with
5 ethanol and the precipitate was dissolved in 50 μ l TEN.
To the dissolved solution (45 μ l) was added EcoRI (350 U
in 70 μ l TEN), EcoRI buffer (20 μ l) and H_2O (65 μ l).
The resulting mixture (200 μ l) was incubated at 37°C for
3 h. Incubation was terminated by phenol treatment and
10 DNA was extracted with ether, precipitated with ethanol,
and dissolved in 40 μ l of TEN. The dissolved solution
was applied to polyacrylamide gel electrophoresis.
After electrophoresis, the DNA segment (1) with cohesive
ends (0.1 μ g in 240 μ l of Tris-acetate buffer) was iso-
15 lated.

ii) Preparation of DNA Segment (2) from pBR322

Plasmid pBR322 was cut with EcoRI by incubation at 37°C for 1 h in a 30 μ l solution containing
plasmid (4.5 μ g in 20 μ l TEN), EcoRI buffer (3 μ l),
20 H_2O (3 μ l), and EcoRI (20 U in 4 μ l TEN). Incubation
was terminated by phenol treatment and DNA was extracted
with ether, precipitated with ethanol, and dissolved in
40 μ l of 10 mM Tris-HCl buffer. The dissolved solution
was treated with 10 μ l of MATE BAP by incubation at 65°C
25 for 1 h. After incubation, MATE BAT was removed by
washing the incubated mixture with 20 μ l of 10mM
Tris-HCl buffer. Thus the DNA segment (2) (4.2 μ g) was

1 recovered in 60 μ l of 10 mM Tris-HCl buffer.

iii) Ligation of DNA Segment (1) and (2)

Segment (1) (0.05 μ g in 120 μ l of Tris-acetate buffer) and Segment (2) (0.14 μ g in 2 μ l of 10 mM

5 Tris-HCl buffer) were mixed and the mixed solution was treated with ethanol. The resulting precipitate was dissolved in 50 μ l of TEN. Forty microliters of the dissolved solution was subjected to ligation using T_4 DNA ligase (0.9 U in 1 μ l TEN), ligase buffer (5 μ l)
10 and ATP (6 mM, 5 μ l TEN) by incubation a 51 μ l solution at 22°C for 2 h. The ligated DNA was precipitated with ethanol and dissolved in 50 μ l of TEN.

iv) Transformation

Twenty microliters of the above ligated DNA
15 solution was used to transform competent cells of strain E. coli C 600. About one thousand five hundred transformants were found to be ampicillin resistant. Restriction enzyme analysis demonstrated that one out of twenty transformants contained pTRL1 plasmid.

20 Preparation of pTRL1 Plasmid

i) Preparation of DNA Segment (3) from pTREI Plasmid

Plasmid pTRE1 was cut with HpaI by incubation at 37°C for 1.5 h in a 40 μ l solution containing Plasmid
25 (2.46 μ g in 30 μ l TEN), HpaI buffer (4 μ l), and HpaI (30 U in 6 μ l TEN). The cut DNA was further cut with ClaI by adding the DNA solution to a 10 μ l solution con-

1 taining ClaI buffer (5 μ l) and ClaI (25 U, 5 μ l TEN),
and by incubating at 37°C for 1.5 h. The doubly cut DNA
was precipitated with ethanol and the precipitate was
dissolved in 40 μ l of TEN. The dissolved solution was
5 applied to agarose gel electrophoresis. After
electrophoresis, the 4640 bp linear DNA Segment (3)
(2.35 μ g in 80 μ l TEN) was isolated.

ii) Preparation of DNA Segment (4) from pTRE1
Plasmid

10 Plasmid pTRE1 was cut with HpaI at 37°C for
1.5 h in a 120 μ l solution containing Plasmid (8.2 μ g in
100 μ l TEN), HpaI buffer (12 μ l), and HpaI (57 U in 8 μ l
TEN). To the above mixture was added a solution con-
taining TaqI (80 U in 9 μ l TEN) and HpaI buffer (12 μ l),
15 and HpaI (57 U in 8 μ l TEN). To the above mixture was
added a solution containing TaqI (80 U in 9 μ l TEN) and
HpaI buffer (1 μ l). The resulting mixture (130 μ l) was
incubated at 65°C for 1 h. After incubation, the doubly
cut DNA was precipitated with ethanol and the precipi-
20 tate was dissolved in 40 μ l TEN. The dissolved solution
was applied to polyacrylamide gel electrophoresis.
After electrophoresis, the 32 bp linear DNA segment (4)
(0.054 μ g in 40 μ l TEN) was isolated.

iii) Ligation of DNA Segment (3) and (4)

25 The mixture containing DNA Segment (3) (0.29
 μ g in 10 μ l TEN), Segment (4) (0.014 μ g in 10 μ l TEN)
was subjected to ligation using T₄ ligase (3.6 U in 4 μ l

1 TEN), ligase buffer (3 μ l), and ATP (6 mM, 3 μ l TEN).
The ligation mixture (30 μ l) was incubated at 22°C for 2
h. The ligated DNA was precipitated with ethanol and
the precipitate was dissolved in 40 μ l TEN.

5 iv) Transformation

Thirty microliters of the above TEN solution
containing the ligated DNA was used to transform com-
petent cells of strain E. coli C600. About eight
hundred and forty transformants were found to be ampi-
10 cillin resistant. All the transformants contained pTRP1
plasmid.

Example 4

Construction of pCR501 Plasmid

15 i) Preparation of DNA Segment (a) from pTRE1
Plasmid

Plasmid pTRE1 was cleaved by incubation at
37°C for 2 h in a 120 μ l reaction mixture containing
Plasmid (8.2 μ g in 100 μ l TEN), EcoRI buffer (12 μ l),
H₂O (3 μ l), and EcoRI (25 U in 5 μ l TEN). After phenol
20 extraction, ether extraction, ethanol precipitation, and
dissolution in 50 μ l TEN, the cut DNA was further cut
with S1 nuclease at 22°C for 1/2 h in a 50 μ l reaction
mixture containing DNA (25 μ l TEN), S1 buffer (5 μ l),
H₂O (10 μ l), and S1 nuclease (100 U, 10 μ l).

25 Incubation was terminated by phenol treatment and DNA
was extracted with ether and precipitated with ethanol.
In the meantime, EcoRI linker was kinased with T₄ poly-

- 1 nucleotide kinase at 37°C for 1 h in a 20 μ l reaction mixture containing the linker (5 μ g, 5 μ l), ATP (3mM, 2 μ l), kination buffer (2 μ l), H₂O (9 μ l) and Kinase (22 U in 2 μ l TEN). The kination mixture (20 μ l) containing
- 5 EcoRI linker was added to the ethanol precipitated cut DNA along with ATP (3 mM, 5 μ l) plus 4.5 units of T₄ ligase (5 μ lTEN). The mixture (30 μ l) was incubated at 22°C for 2 h. The product DNA was precipitated with ethanol and the precipitate was dissolved in 60 μ l TEN.
- 10 To the DNA solution (50 μ l) was added EcoRI (500 U in 50 μ l TEN), EcoRI buffer (20 μ l), and H₂O (80 μ l). The resulting mixture (200 μ l) was incubated at 37°C for 2 h. Incubation was terminated by phenol treatment and DNA was extracted with ether and precipitated with etha-
- 15 nol. The precipitated DNA was cut with SalI by incubation at 37°C for 1.5 h in a 110 μ l solution containing SalI (100 U, 20 μ l), SalI buffer (10 μ l), H₂O (80 μ l). After incubation, the cut DNA was precipitated with ethanol and dissolved in 60 μ l TEN.
- 20 The DNA was subjected to agarose gel electrophoresis, yielding 3.5 μ g of the purified linear DNA (a)(4210 bp) in 100 μ l TEN.

ii) Preparation of DNA Segment (b) from pCR301 Plasmid

- 25 Plasmid pCR301 was cut with KpnI by incubation at 37°C for 1.5 h in a 120 μ l solution containing Plasmid (7.3 μ g in 100 μ l TEN), KpnI buffer (12 μ l),

1 H₂O (2 µl), and KpnI (35 U, 6 µl TEN). To the mixture
was added EcoRI buffer solution (14 µl) containing EcoRI
(30 U, 6 µl TEN). The 140 µl mixture was incubated at
37°C for 1 h. The doubly cut DNA was precipitated with
5 ethanol and the precipitate was dissolved in 60 µl TEN.
The dissolved solution was applied to polyacrylamide gel
electrophoresis. After electrophoresis, the 246 bp DNA
Segment (b) (0.03 µg in 4 µl TEN) was isolated.

iii) Preparation of DNA Segment (c) from
10 pCR301 Plasmid

Plasmid pCR301 was cut with KpnI by incubation
at 37°C for 1.5 h in a 120 µl solution containing
Plasmid (15 µg in 100 µl TEN), KpnI buffer (12 µl),
H₂O (2 µl), and KpnI (35 U, 6 µl TEN). A 14 µl SalI
15 buffer solution plus SalI (32 U, 4 µl TEN), H₂O (2 µl)
was added to the above incubated mixture. The 140 µl
mixture was further incubated at 37°C for 1 h. The
doubly cut DNA was precipitated with ethanol and the
precipitate was dissolved in 60 µl TEN. The dissolved
20 solution was applied to agarose gel electrophoresis.
After electrophoresis, the 1025 bp DNA Segment (c) (2.15
µg in 180 µl TEN) was isolated.

iv) Ligation of DNA Segments (a), (b) and (c)
The mixture containing DNA Segment (a) (1 µg
25 in 30 µl TEN), Segment (b) (0.03 µg in 4 µl TEN), and
Segment (c) (0.4 µg in 30 µl TEN) was lypophilized.
After lypophilization, the precipitate was rinsed with

- 1 ethanol. Each precipitated segment was ligated together
in a 20 μ l solution containing ligase buffer (4 μ l), ATP
(3 mM, 4 μ l), H₂O (1 μ l) and T₄ ligase (0.9 U, 1 μ l).
Incubation was continued for 2 h at 22°C. The ligated
5 DNA was precipitated with ethanol and dissolved in 40 μ l
TEN.

v) Transformation

- The TEN buffer solution (30 μ l) containing the
above ligated DNA was employed for transformation of E.
10 coli strain C600. Twenty transformants were found to
contain plasmid pCR501. One of them was deposited with
the FRI as E. coli C600 $r_k^- m_k^-$ (pCR501) FERM BP 262.

Example 5

Construction of pCR601 Plasmid

- 15 i) Preparation of DNA Segment (d) from pTRE1
Plasmid

- Plasmid pTRE1 was cut with HpaI by incubation
at 37°C for 1 h in a 40 μ l solution containing Plasmid
(2.46 μ g in 30 μ l TEN), HpaI buffer (4 μ l), and HpaI (35
20 U, 6 μ l TEN). To the incubated mixture was then added a
10 μ l solution containing SalI buffer (5 μ l) and SalI
(20 U, 5 μ l TEN). The mixture (50 μ l) was further incu-
bated at 37°C for 1 h. The doubly cut DNA was precipi-
tated with ethanol and the precipitate was dissolved in
25 40 μ l TEN. The dissolved solution was applied to
agarose gel electrophoresis. After electrophoresis, the
4010 bp Segment (d) (2.0 μ g in 40 μ l TEN) was isolated.

1 ii) Preparation of DNA Segment (e) from pTRL1
Plasmid

Plasmid pTRL1 was cut with HpaI by incubation at 37°C for 1.5 h in a 120 µl solution containing
5 Plasmid (15.4 µg in 100 µl TEN), HpaI buffer (12 µl),
and HpaI (25 U, 5 µl TEN), and H₂O (3 µl). To the
incubated mixture was then added a 20 µl solution con-
taining EcoRI buffer (914 µl) and EcoRI (30 U, 6 µl
TEN). The mixture (140 µl) was further incubated at
10 37°C for 1 h. The doubly cut DNA was precipitated with
ethanol and the precipitate was dissolved in 40 µl TEN.
The dissolved solution was applied to polyacrylamide gel
electrophoresis. After electrophoresis, the 56 bp
Segment (e) (0.18 µg in 40 µl TEN) was isolated.

15 iii) Preparation of DNA Segment (b) from
pCR301 Plasmid

By repeating the procedure of Example 4, but
using 32 units of KpnI and 30 units of EcoRI, plasmid
pCR301 was cut with KpnI and then with EcoRI to afford
20 0.46 µg (in 40 µl TEN) of the 246 bp DNA segment after
polyacrylamide gel electrophoresis.

iv) Preparation of DNA Segment (c) from pCR301
Plasmid

By repeating the procedure of Example 4, but
25 using 30 units of KpnI and 24 units of SalI, plasmid
pCR301 was cut with KpnI and then with SalI to afford
3.9 µg (in 40 µl TEN) of the 1025 bp DNA segment after

1 agarose gel electrophoresis.

v) Ligation of DNA Segments (b), (c), (d) and (e)

The mixture containing DNA Segment (b) (0.06 μ g in 5 μ l TEN) Segment 9c) (0.49 μ g in 5 μ l TEN),
5 Segment (d) (0.5 μ g in 10 μ l TEN), and Segment (e) (0.49 μ g in 5 μ l TEN) was subjected to ligation using
T₄ ligase (5.5 U in 6 μ l TEN) and ligation buffer (4.5 μ l) plus ATP (6 mM, 4.5 μ l). The ligated mixture (45
10 μ l) was incubated at 22°C for 2 h. The ligated DNA was precipitated with ethanol and dissolved in 60 μ l TEN.

vi) Transformation

The TEN buffer solution (20 μ l) containing the above ligated DNA was used to transform E. coli C600
15 $r_k^- m_k^-$ strain. Twenty seven ampicillin resistant transformants were obtained after transformation. Eight transformants were found to contain pCR601 as determined by restriction enzyme digestion. This strain E. coli C600 $r_k^- m_k^-$ (pCR601) was deposited with the FRI as FERM
20 BP263.

Example 6

Construction of pCR701 Plasmid

i) Preparation of DNA Segment (f) from pTRP 1 Plasmid

25 Plasmid pTRP1 was cut with HindIII by incubation at 37°C for 1 h in a 120 μ l solution containing Plasmid (25.2 μ g in 100 μ l TEN), Hind III buffer (12

1 μ l), and Hind III (48 U, 8 μ l TEN). To the incubated
mixture was added SalI (24U, 6 μ l TEN) and SalI buffer
(14 μ l). The resulting 140 μ l solution was incubated at
37°C for 2 h. The doubly cut DNA was precipitated with
5 ethanol and the precipitate was dissolved in 60 μ l TEN.
The dissolved solution was applied to agarose gel
electrophoresis. After electrophoresis, the 4051 bp
linear DNA Segment (f) (8.2 μ g in 120 μ l TEN) was iso-
lated.

10 ii) Preparation of DNA Segment (g) from pCR501
Plasmid

Plasmid pCR501 was cut with SalI by incubation
at 37°C for 1 h in a 120 μ l solution containing Plasmid
(39 μ g in 100 μ l TEN), SalI buffer (12 μ l), and SalI (32
15 U, 8 μ l TEN). The cut DNA was partially digested with
BamH I by addition of BamH I (25 U, 5 μ l TEN) to the
above mixture and by incubation at 22°C for 1/2 h. The
product DNA was precipitated with ethanol and the preci-
pitate was dissolved in 60 μ l TEN. This dissolved solu-
20 tion was applied to agarose gel electrophoresis. After
electrophoresis, the 1264 bp DNA Segment (g) (2 μ g in 80
 μ l TEN) was isolated.

iii) DNA Segment (h)

A synthetic oligonucleotide having the
25 following sequence was obtained:

5' AGCTTATGGCTGAGATCACCAG 3'
 ATACCGACTCTAGTGGTCCTAG 5'

1 iv) Ligation of DNA Segments (f), (g) and (h)

 The mixture containing DNA Segment (f) (0.68
 μg in 10 μl TEN), Segment (g) (0.25 μg in 10 μl TEN),
 and Segment (h) (0.046 μg in 10 μl TEN) was subjected to
5 ligation using T₄ DNA ligase (1.8 U, in 2 μl TEN) and
 ligation buffer (4 μl) plus ATP (6 mM, 4 μl TEN). The
 ligated mixture DNA was precipitated with ethanol and
 dissolved in 50 μl TEN.

 v) Transformation

10 Twenty microliters of the above ligation reac-
 tion mixture was used to transform competent cells of E.
 coli C600. Eight ampicillin resistant transformants
 were obtained and, by restriction enzyme analysis, four
 of these transformants were found to have pCR701. This
15 strain E. coli C600 r_k-m_k- (pCR701) was deposited with
 the FRI as FERM BP 264.

Example 7

Expression of Prochymosin in E. coli

E. coli strain harboring pCR501, pCR601 or
20 pCR701 was preliminarily cultivated in LB at 37°C over-
 night. One milliliter of the culture broth was then
 transferred to M9 medium (10 ml), and cultivated for 1
 h. Cultivation was continued at 37°C for additional 3
 to 4 h after 3-beta-indolyacrylic acid (15 mg/l) was
25 added to the medium. Cells were harvested by centrifuga-
 tion at 15,000 rmp for about 15 min, and suspended in
 3 ml of PBS buffer (150 mM NaCl in 20 mM sodium

1 phosphate buffer, pH 7.0) which contains 1 mM PMSF
(phenylmethylsulfonyl fluoride). To this suspension was
added 60 μ l of 250 mM EDTA and 30 μ l lysozyme (10 ml/l)
and the mixture was kept at 0°C for 1/2 h. The resulting
5 spheroplasts were disrupted by sonication and to this was
added 3.09 ml of 8 M urea. The cell lysate mixture was
incubated at 37°C for 1 h. After centrifugation at 3000
rpm for 1/2 h, the supernatant solution was dialyzed
against PBS. The dialysate was applied to the binding
10 competitive radioimmunoassay (see, Nishimori et al.,
Gene). By radioimmunoassay prochymosin was immunopreci-
pitated and the amount of the radioactive element (^{125}I)
was measured with a gamma-ray counter. In the meantime,
calibration curves were prepared by varying the con-
15 centration of authentic prochymosin. By comparing the
count of the immunoprecipitated prochymosin with the
calibration curves, the amount of prochymosin in the
cell lysate was determined. This experiment
demonstrated that the expression level of prochymosin
20 was highest with the culture broth from E. coli con-
taining pCR501 (about 300,000 molecules per host cell)
and lowest with that from E. coli containing pCR701.

Independantly, the above sonicated cell-free
extract was treated with 4M urea. After centrifugation,
25 the supernatant solution was applied to
SDS-polyacrylamide gel electrophoresis, and the migrated
proteins were then blotted onto nitrocellulose filters.

1 These filters were analyzed on autoradiography as previously described in Nishimori et al., Gene. For each bacterial extract, a distinctive band corresponding to that of prochymosin was observed. By comparing the density of these bands, it was determined that E. coli containing pCR501 plasmid produced about 300,000 prochymosin molecules per cell. The ability of each expression plasmid-containing host cell to produce prochymosin was evaluated to be in the order of pCR501 \geq PCR601 > PCR701. This trend is well in accord with the results from the radioimmunoassay method.

Renaturation and Activation of Bacterial Prochymosin and Milk-Clotting Activity

Total sonicates of plasmid-containing bacteria were treated with 8M urea and dialyzed against 25 mM sodium bicarbonate (pH 10.0) in order to remove urea. After another dialysis against 50 mM Tris-HCl buffer (pH 7.5), dialysates were activated by addition of 0.4 M glycine (pH 2.3) and by maintaining the solution at room temperature for 15 min.

The milk-clotting activity of each bacterial extract was tested according to the method of Foltman (B. Foltman, Prochymosin and Chymosin Methods in Enzymology, 19, 42 (1972)). In this test, the milk-clotting activity to coagulate 10 ml of skim milk within 100 sec at 30° may be defined as one chymosin unit (CU). For each bacterial extract derived from the expression

- 1 plasmids, the milk-clotting activity was measured after
activation of the prochymosin so-produced (viz. conver-
sion of bacterial prochymosin to chymosin); the activity
for pCR501 was 9.3 CU/mg and 3.7 CU/mg for pCR701. It
5 should be recognized that a bacterial extract harboring
no expression plasmid displayed no milk-clotting acti-
vity at all as determined by the above testing
procedures.

WHAT IS CLAIMED IS:

1. A method for expressing a prochymosin coding gene in E. coli host cells, wherein said gene is derived from a recombinant plasmid containing cloned prochymosin cDNA, said method comprising:

isolating said gene; attaching by ligation a transcriptional promoter and a translational initiation codon thereto to form an expression plasmid; introducing the expression plasmid into host cells by transformation; and selecting transformed cells that have high levels of expression of prochymosin, said gene having at least from the fifth coding codon to the end of the coding sequence (365th codon) for prochymosin.

2. A method according to claim 1 wherein said recombinant plasmid is plasmid pCR 301; said host cells are E. coli c 600 $r_k^- m_k^-$; and said transcriptional promoter is the E. coli trp operon promoter.

3. A method according to claim 1 wherein said expression plasmid is pCR501, pCR601 or pCR701.

4. A method for expressing a prochymosin coding gene in E. coli host cells, wherein said gene is derived from a recombinant plasmid containing cloned prochymosin cDNA, said method comprising:

isolating said gene; ligating onto said gene a synthetic oligonucleotide carrying a complementary portion of the prochymosin coding sequence which has been deleted from said gene; attaching thereto by ligation a

transcriptional promotor and a translational initiation codon when not present in said synthetic oligonucleotide to form an expression plasmid; introducing the expression plasmid into host cells by transformation; and selecting transformed cells that have high levels of expression of prochymosin, said synthetic oligonucleotide optionally carrying a translational initiation codon.

5. A method according to claim 4 wherein said recombinant plasmid is pCR301 plasmid; said host cells are E. coli c 600 $r_k^- m_k^-$; and said transcriptional promoter is the E. coli trp operon promoter.

6. A method according to claim 4 wherein said expression plasmid is pCR701.

7. An expression plasmid comprising a prochymosin coding gene and a vector operatively attached thereto, said vector being originally derived from pBR322 plasmid and containing a transcriptional promoter and a translational initiation codon.

8. An expression plasmid according to claim 7 wherein said prochymosin coding gene is the nucleotide sequence from the fifth codon to the end of the coding sequence (365th codon); said transcriptional promoter is the E. coli trp operon promoter; and said translational initiation codon is ATG codon.

9. An expression plasmid according to claim 7 wherein said prochymosin coding gene is a nucleotide

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sequence from the first codon to the end of the coding sequence (365th codon) for prochymosin; and said transcriptional promoter is the E. coli trp operon promoter.

10. An expression plasmid according to claim 8 wherein said translational initiation codon is within the trp L or trp E region.

11. An expression plasmid according to claim 10 wherein said coding gene is fused to the following DNA sequence at its 5' end

5' -AGAGAATTACAATGCAAACACAAAAACCGACTGGGGAATTC-3'
SD

12. An expression plasmid according to claim 10 wherein said coding gene is fused to the following DNA sequence at its 5' end

5' -AAGGGTATCGACAATGAAAGCAATTTTCGTGGAATTC-3'
SD

13. An expression plasmid according to claim 9 wherein said translational initiation codon is within the trp L region.

14. An expression plasmid according to claim 13 wherein said translational initiation codon proceeds the first codon of the prorennin coding sequence.

15. An expression plasmid according to claim 14 wherein said coding gene is fused to the following DNA sequence at its 5' end:

5' -AAGGGTATCGATAAGCTATG-3'
SD

16. Prochymosin gene comprising a nucleotide sequence from the first codon (GCT) to the 365th (ATC) codon.
17. Prochymosin gene according to claim 16 which further comprising ATG codon proceeding said first codon.
18. Prochymosin gene comprising a nucleotide sequence from the fifth codon (CGG) to the 365th codon (ATC).
19. A method for making pTRE1 plasmid which comprises the steps of:
 - (1) partially digesting pOCT2 with EcoRI in order to cut the EcoRI site closer to the Ap^r gene portion;
 - (2) repairing the cut single-stranded DNA parts by means of DNA polymerase; and
 - (3) combining the repaired cut ends together by ligation using T₄ DNA ligase.
20. A method for making pTRL 1 plasmid which comprises the steps of:
 - (a) digesting pOCT2 with EcoRI and partially with RsaI to produce a linear DNA segment;
 - (b) ligating thereto the kinased EcoRI linker followed by digestion with EcoRI to produce DNA segment (1);
 - (c) digesting pBR322 plasmid with EcoRI followed by treatment with MATE BAP to produce DNA

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segment (2); and

- (d) ligating DNA segments (1) and (2) by means of T_4 DNA ligase.

21. A method for making pTRP1 plasmid which comprises the steps of:

- (a) digesting pTRE1 plasmid with HpaI and ClaI successively to produce DNA segment (3);
- (b) digesting pTRE1 with HpaI and TaqI successively to produce DNA segment (4); and
- (c) ligating DNA segments (3) and (4) by means of T_4 DNA ligase.

22. A method for making pCR501 plasmid which comprises the steps of:

- (a) digesting pTRE 1 plasmid with EcoRI and S1 successively to produce a linear DNA segment with blunt ends;
- (b) ligating the EcoRI linker thereto followed by digestion with EcoRI and SalI to produce linear DNA segment (a);
- (c) digesting pCR 301 with KpnI and EcoRI successively to produce linear DNA Segment (b);
- (d) independently digesting pCR301 with KpnI plus SalI to produce DNA segment (c); and
- (e) ligating DNA segments (a), (b) and (c) together by means of T_4 DNA ligase.

23. A method for making pCR601 plasmid which comprises the steps of:

- (a) digesting pTRE1 plasmid with HpaI and SalI successively to produce linear DNA segment (d);
- (b) digesting pTRL1 plasmid with HpaI and EcoRI successively to produce linear DNA segment (e);
- (c) digesting pCR301 plasmid with KpnI plus EcoRI, and with KpnI plus Sal I respectively to produce DNA segment (b) and segment (c); and
- (d) ligating DNA segments (b), (c), (d) and (e) together by means of T_4 DNA ligase.

24. A method for making pCR701 plasmid which comprises the steps of:

- (a) digesting pTRP1 plasmid with HindIII and SalI successively to produce linear DNA segment (f);
- (b) digesting pCR501 plasmid with SalI and partially with BamHI to produce DNA segment (g);
- (c) obtaining a synthetic oligonucleotide (DNA segment (h)) having the nucleotide sequence of

$$\begin{array}{c}
 3' \\
 5' \text{ AGCTTATGGCTGAGATCACCAG} \\
 \text{ATACCGACTCTAGTGGTCCTAG} 5' \\
 3'
 \end{array}$$
 ; and

- (d) ligating DNA segments (f), (g) and (h) together by means of T_4 DNA ligase.
25. A recombinant plasmid found in E. coli FRI
Accession number FERM BP 262.

26. A Recombinant plasmid found in E. coli FRI
Accession number FERM BP 263.
27. A Recombinant plasmid found in E. coli FRI
Accession number FERM BP 264.
28. A method for producing prochymosin by means of
expression of a prochymosin coding gene in E. coli host
cells,

wherein said gene is derived from a recom-
binant plasmid containing cloned prochymosin cDNA, said
method comprising:

isolating said gene; attaching by ligation a
transcriptional promoter and a translational initiation
codon thereto to form an expression plasmid; introducing
the expression plasmid into host cells by
transformation; selecting transformed cells that have
high levels of expression of prochymosin; and growing
said cells in a nutrient medium.

29. A method according to claim 28 wherein said
recombinant plasmid is pCR301 plasmid; said host cells
are derived from E. coli C 600 $r_k^-m_k^-$; and said
transcriptional promoter is the E. coli trp operon
promoter.
30. A method according to claim 28 wherein said
expression plasmid is selected from the group consisting
of pCR501, pCR601, and pCR701; and said host cells are
derived from E. coli C 600 $r_k^-m_k^-$.
31. A method according to claim 28 wherein said

transformed cells are found in a deposited E. coli strain selected from the group consisting of Accession number FERM BP262, FERM BP263 and FERM BP264.

32. Calf Prochymosin produced by the method of claim 28.

33. E. coli strain capable of producing prochymosin which contains an expression plasmid, said plasmid being selected from the group consisting of pCR501, pCR601 and pCR701.

34. E. coli strain as deposited in the FRI Accession number FERM BP262.

35. E. coli strain as deposited in the FRI Accession number FERM BP263.

36. E. coli strain as deposited in the FRI Accession number FERM BP264.

FIG. 1a

-20
 TGCTACTGTGCTCTTCGCTCTCTCCAGGGC
 LeuLeuAlaValPheAlaLeuSerGlnGly

20 40 60 80 100
 GCTGAGATCACCAGGATCCCTCTGTACAAAGGCAAGTCTCTGAGGAAGGCGCTGAAGAGCATGGGCTTCTGGAGGACTTCCTGCAGAAACAGCAGTATG
 AlaGluIleThrArgIleProLeuTyrLysGlyLysSerLeuArgLysAlaLeuLysGluHisGlyLeuLeuGluAspPheLeuGlnLysGlnGlnTyrG

120 140 160 180 200
 GCATCAGCAGCAAGTACTCCGGCTTCGGGGAGGTGGCAGCGTGCCCTGACCAACTACCTGGATAGTCAGTACTTTGGGAAGATCTACCTGGGACCC
 yIleSerSerLysTyrSerGlyPheGlyGluValAlaSerValProLeuThrAsnTyrLeuAspSerGlnTyrPheGlyLysIleTyrLeuGlyThrPr

220 240 260 280 300
 GCCCCAGGAGTTCACCGTGTCTTGACACTGGCTCCTCTGACTTCTGGGTACCTCTATCTACTGCAAGAGCAATGCCTGCAGAAACACCAGCGCTTC
 oProGlnGluPheThrValLeuPheAspThrGlySerSerAspPheTrpValProSerIleTyrCysLysSerAsnAlaCysLysAsnHisGlnArgPhe

320 340 360 380 400
 GACCCGAGAAAGTCGTCCACCTTCAGAACCTGGGCAAGCCCTGTCTATCCACTACGGGACAGGAGCATGCAGGGCATCTGGGCTATGACACCGTCA
 AspProArgLysSerSerThrPheGlnAsnLeuGlyLysProLeuSerIleHisTyrGlyThrGlySerMetGlnGlyIleLeuGlyTyrAspThrValT

420 440 460 480 500
 CTGTCTCCAACATTGTGGACATCCAGCAGACAGTAGGCCTGAGCACCAGGAGCCCGGGGACGCTTTCACCTATGCCGAATTCGACGGGATCCTGGGGAT
 hrValSerAsnIleValAspIleGlnGlnThrValGlyLeuSerThrGlnGluProGlyAspValPheThrTyrAlaGluPheAspGlyIleLeuGlyMe

520 540 560 580 600
 GGCTTACCCCTCGCTCAGAGTACTCGATACCCGTGTTTGACAACATGATGAACAGGCACCTGGTGGCCCAAGACCTGTTCTCGGTTTACATGGAC
 tAlaTyrProSerLeuAlaSerGluTyrSerIleProValPheAspAsnMetMetAsnArgHisLeuValAlaGlnAspLeuPheSerValTyrMetAsp

FIG. 1b

620	640	660	680	700
AGGAATGCCAGGAGCATGCTCACGCTGGGGCCATCGACCCGTCCTACTACACAGGGTCCCTGCACCTGGGTGCCCGTGACAGTGCAGCAGTACTGGC				
ArgAsnGlyGlnGlnSerMetLeuThrLeuGlyAlaIleAspProSerTyrTyrThrGlySerLeuHisThrValProValThrValGlnGlnTyrTrpG				
(Asp)				
720	740	760	780	800
AGTTCACCTGTGGACAGTGTACCATCAGCGGTGTGGTGTGGCTGTGAGGGTGGCTGTACAGGCCATCTCTGGACACGGGCACCTCCAAAGCTGGTGGGCC				
inPheThrValAspSerValThrIleSerGlyValValValAlaCysGlnGlyGlyCysGlnAlaIleLeuAspThrGlyThrSerLysLeuValGlyPr				
820	840	860	880	900
CAGCAGCGACATCCTCAACATCCAGCAGGCCATTGGAGGCCACACAGAACCAAGTACGATCGACTGCACAAACCTGAGCTACATGCCCCACT				
oSerSerAspIleLeuAsnIleGlnGlnAlaIleGlyAlaThrGlnAsnGlnTyrAspGluPheAspIleAspCysAspAsnLeuSerTyrMetProThr				
920	940	960	980	1000
GTGGTCTTTGAGATCAATGGCAAAATGTACCCACTGACCCCTCCGCCTATACCAAGCCCAAGACAGGGCTTCTGTACCAAGTGGCTTCCAGAGTGAATC				
ValValPheGluIleAsnGlyLysMetTyrProLeuThrProSerAlaTyrThrSerGlnAspGlnGlyPheCysThrSerGlyPheGlnSerGluAsnH				
1020	1040	1060	1080	1100
ATTCCAGAAATGGATCCTGGGGATGTTTTCATCCGAGAGTATTACAGCGTCTTTGACAGGGCCAAACCTCGTGGGCTGGCCAAACCATCTGATC				
AsSerGlnLysTrpIleLeuGlyAspValPheIleArgGluTyrTyrSerValPheAspArgAlaAsnAsnLeuValGlyLeuAlaLysThrIle				
(Ala)				
1120	1140	1160	1180	1200
ACATCGCTGACCAAGAACCTCACTGTCCCCACACACCTGCACACACATGTACATGAGCAGCATGTGCACACACAGATGAGGTTTCCAGA				
1220	1240			
CAGATGATTCTCAATAACGTTGCTCTTCTGCAAAAAA				

FIG. 2

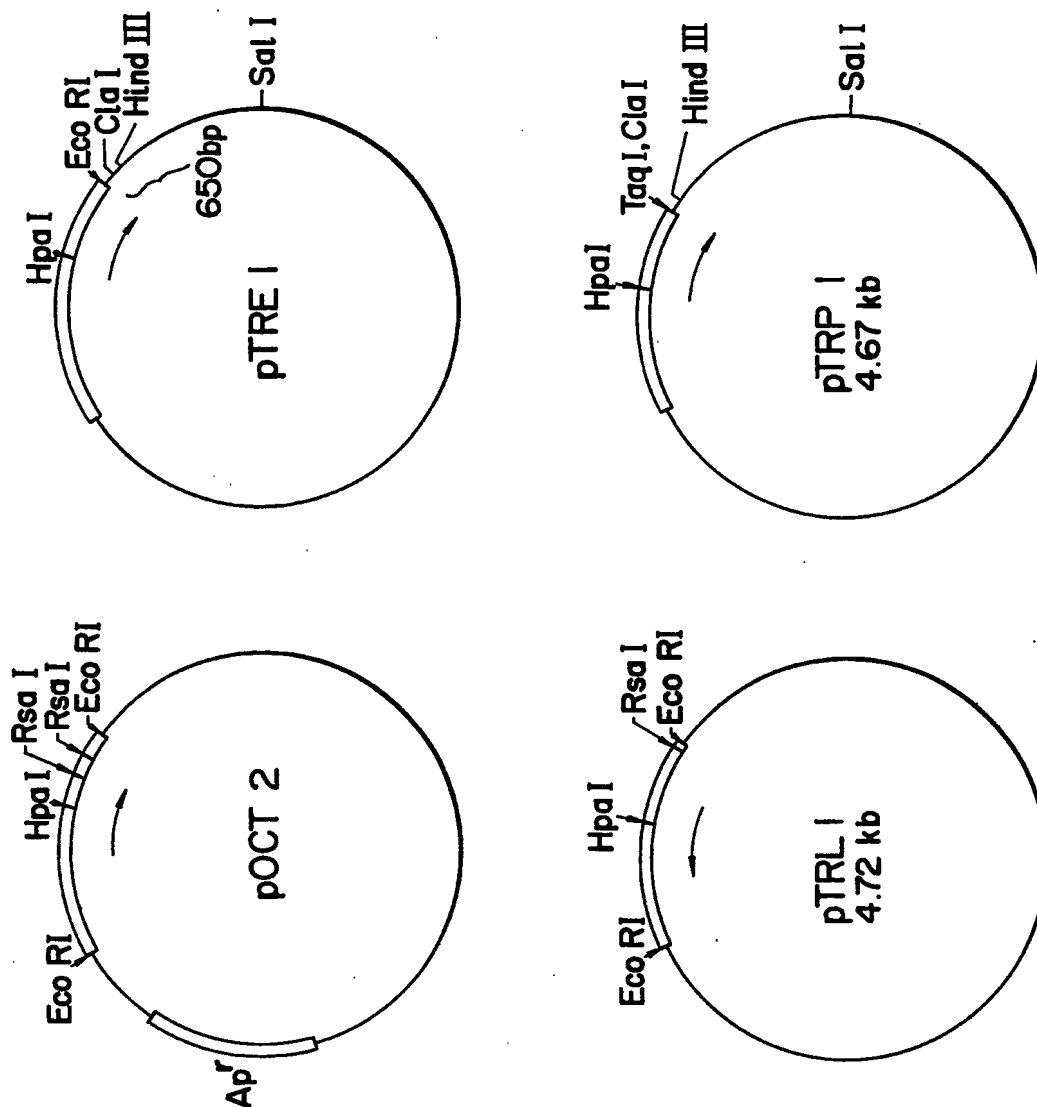


FIG. 3

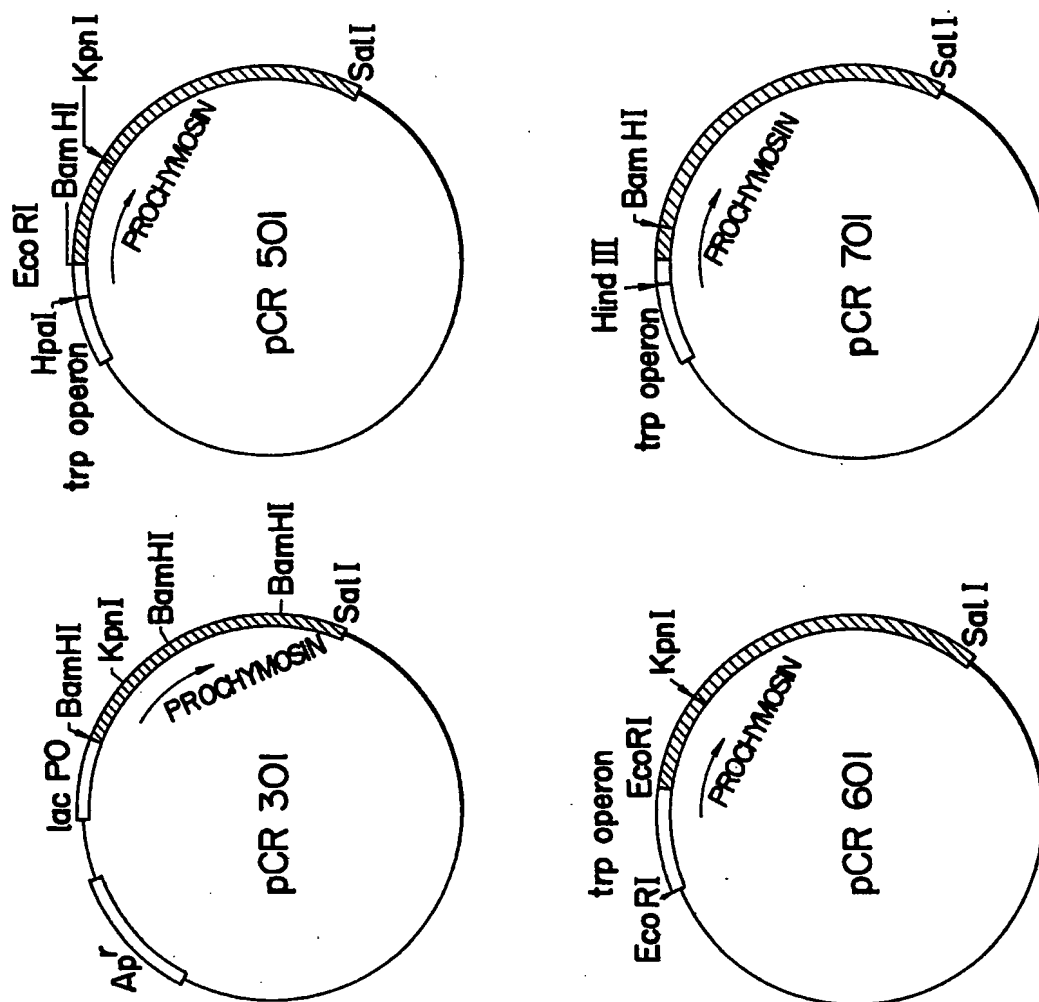


FIG. 4

5' CTCAAGGCGCACTCCCGTTCTGGATAATGTTTTTTCGCCGA
CATCATAACGGTTCTGGCAAATATTCTGAAATGAGCTGTTGA
CAATTAATCATCGAACTAGTTAACTAGTACGCAAGTTCACGT
Trp L AAAAAGGGTATCGACAATGAAAGCAATTTTCGTACTGAAAGG
 SD
TTGGTGGCGCACTTCCTGAAACGGGCAGTGTATTCACCATGC
GTAAAGCAATCAGATACCCAGCCCGCCTAATGAGCGGGCTTT
Trp E TTTTGAACAAAATTAGAGAATAACAATGCAAACACAAAAC
 EcoRI SD
 ↓ ↓
CGACTGGAATTCTC 3'

FIG. 5

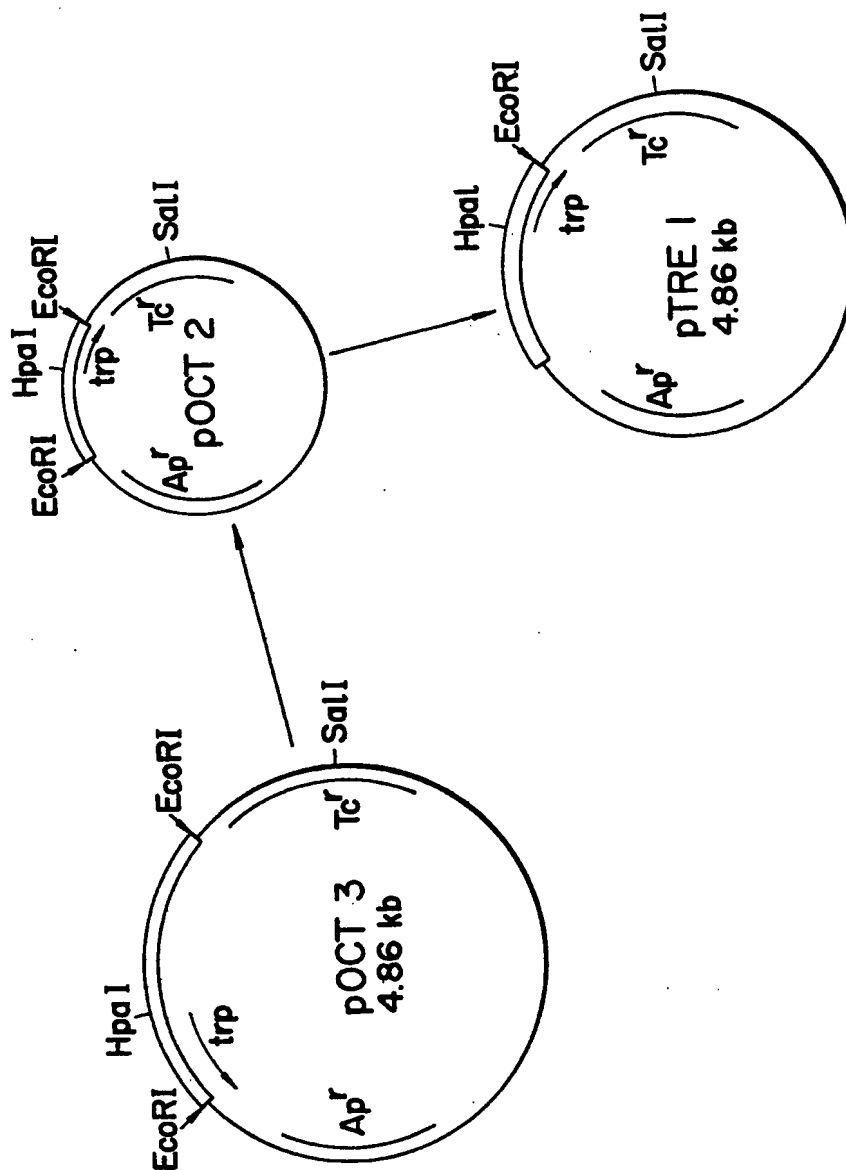


FIG. 6

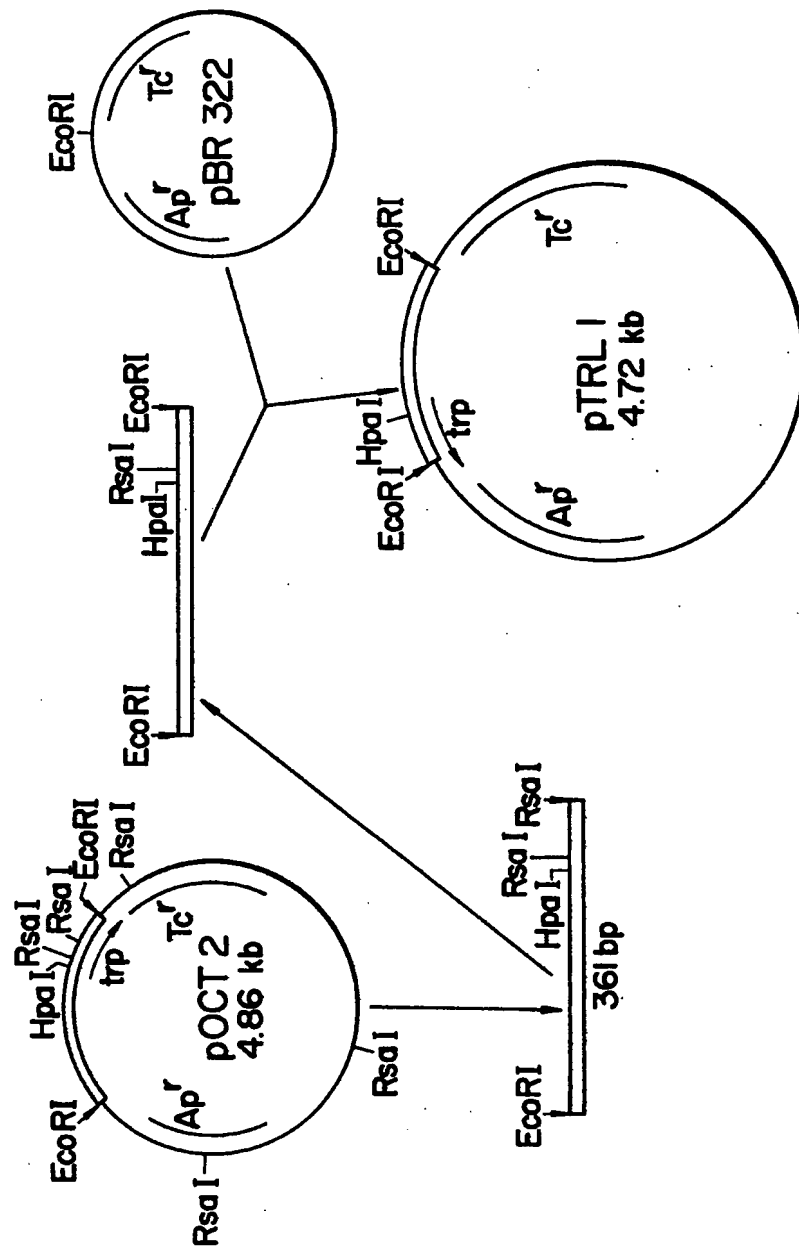


FIG. 7

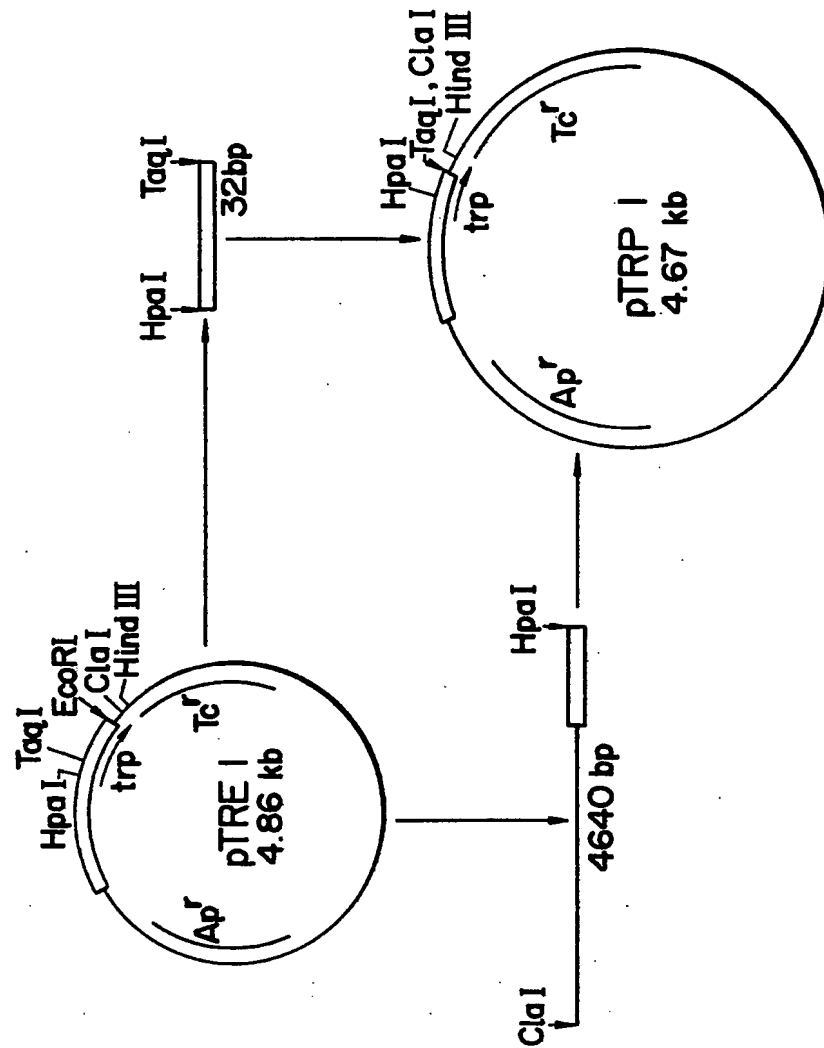


FIG. 8

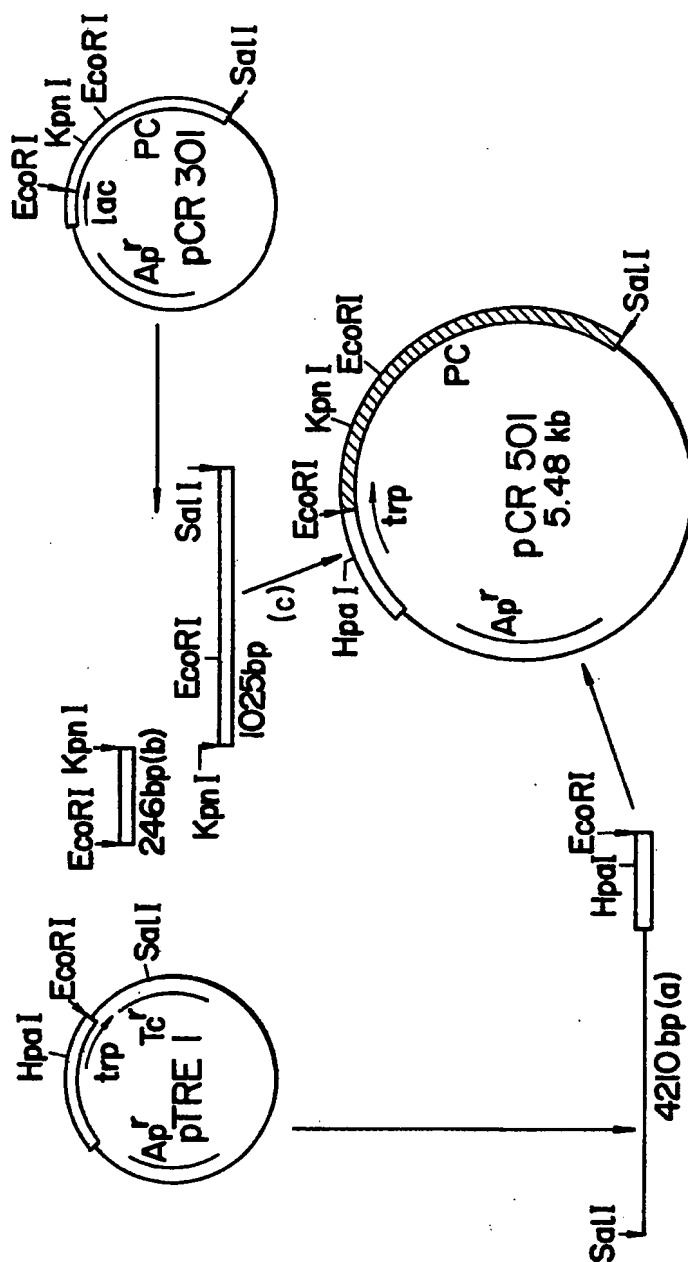


FIG. 9

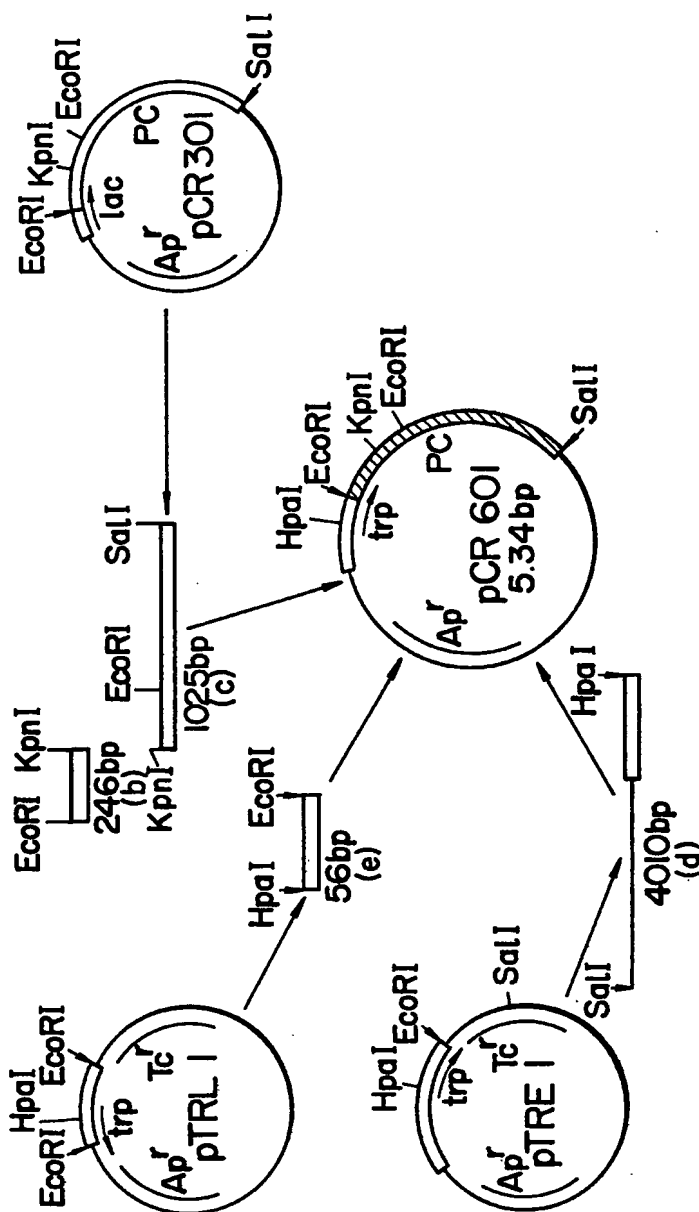
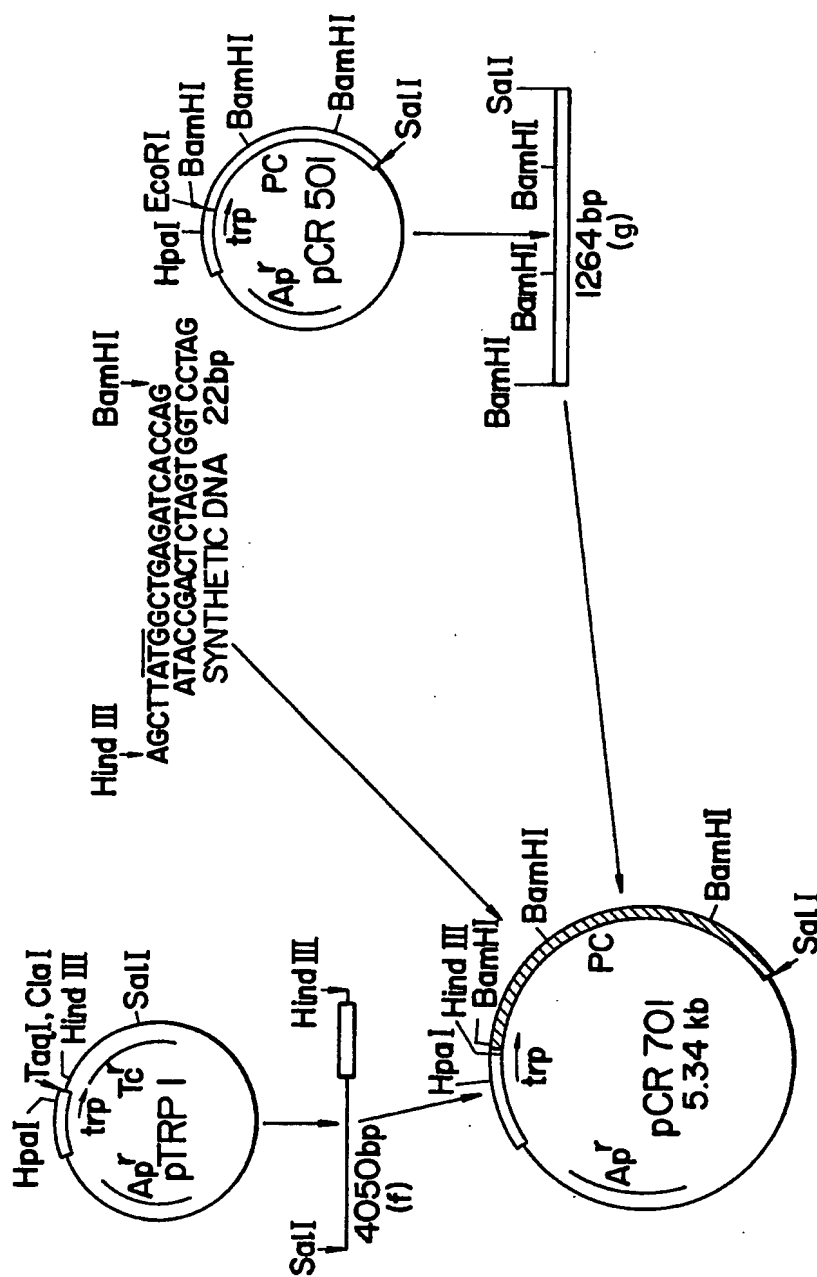


FIG. 10





European Patent
Office

EUROPEAN SEARCH REPORT

0121775 Application number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 84102451.6
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
X,D	<p>EP - A2 - 0 073 029 (BEPPU)</p> <p>* Abstract; claims 1-4,10-13, 17-21 *</p> <p>& JP-A2-56-131 631, Kokai-no. 32896/83</p> <p>--</p>	1,2,4, 5,7, 28-30, 32	<p>C 12 N 15/00</p> <p>C 12 N 9/50//</p> <p>C 12 R 1/19</p>
A,D	<p>GENE, vol. 19, 1982, (Amsterdam, NL)</p> <p>K. NISHIMORI et al.: "Expression of cloned calf prochymosin gene sequence in Escherichia coli" pages 337-344</p> <p>* The whole article *</p> <p>--</p>	1,2,4, 5,7-9, 28,29	
A,D	<p>THE JOURNAL OF BIOCHEMISTRY, vol. 90, 1981, (Tokyo, JP)</p> <p>K. NISHIMORI et al.: "Cloning in Escherichia coli of the Structural Gene of Prorennin, the Precursor of Calf Milk-Clotting Enzyme Rennin" pages 901-904</p> <p>* The whole article *</p> <p>--</p>	1,2,4, 5,7-9, 28,29	<p>TECHNICAL FIELDS SEARCHED (Int. Cl. 7)</p> <p>C 12 N</p>
A,D	<p>EP - A2 - 0 068 691 (CELLTECH LIMITED)</p> <p>* Abstract; claim 4 *</p> <p>--</p>	1,4,28	
A,D	<p>EP - A2 - 0 057 350 (COLLABORATIVE RESEARCH INC.)</p> <p>* Claims 7-9 *</p> <p>----</p>	1,4,28	
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 07-06-1984	Examiner WOLF
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>& : member of the same patent family, corresponding document</p>			